forest management note

Note No. 35 Northern Forestry Centre Edmonton, Alberta

FOREST FIRE GROWTH CALCULATOR

Since the introduction of the interim edition of the Canadian Forest Fire Behavior Prediction (FBP) System[1] (Lawson et al. 1985), behavior prediction has been used in a variety of ways to aid in decision making. Although the process of predicting fire behavior is not complex, the use of tables and computers is not always feasible in the field. As an alternative, a pocket-sized slide-rule calculator (Fig. 1) was developed at the Northern Forestry Centre for estimating forest fire growth. This *Note* describes the operation of the fire growth calculator (FGC) for fast field application of the FBP System.

The fire growth calculator will simplify and speed up the process of making fire behavior predictions using the FBP System. Field personnel will be able to make quick estimates of fire growth without the aid of an electronic calculator. Familiarity with the FBP System, achieved through agency training, is essential for proper use of the FGC. In addition, accurate current weather conditions and an understanding of the adjustment procedures are necessary to produce the best possible growth estimate.

The FGC employs the principles of the old-style logarithmic slide rule for multiplication, division, and power (exponential) operations to calculate the head fire rate of spread (ROS), spread distance, perimeter, and area of elliptically shaped fires (Fig. 2) and to determine crowning potential for 14 fuel types. The logarithmic scales on the FGC facilitate these mathematical operations and extend the upper and lower scale limits with no crowding or loss of accuracy.

The FBP System is the second major subsystem of the Canadian Forest Fire Danger Rating System (CFFDRS), the first being the Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service 1984; Van Wagner and Pickett 1985). The two subsystems are closely linked, as the FWI System provides the fire weather information that in the FBP System is combined with topography and fuel characteristics to produce quantitative estimates of fire behavior. Because the FGC utilizes elements from both subsystems to produce estimates of fire growth (i.e., perimeter length and area), a basic understanding of both subsystems is essential to the operation of the FGC. Unlike the two subsystems, the FGC uses (1) a different style of chart format to present the Initial Spread Index (ISI); (2) a focus approach (Alexander 1985) to calculate length-to-breadth (L/B) ratios and ultimately perimeter length and area; and (3) three broad fuel type categories to estimate length-to-breadth relationships (Alexander 1985).

The inherent limitations of slide-rule devices of this kind prevent precise results; however, the estimates produced from this calculator should provide a sufficiently accurate estimation of a fire's general growth potential under most conditions. Scale range is the main limiting factor in the FGC, the ranges being:

Rate of spread	= 3–70 m/min
Elapsed time	= 10–90 min
Spread distance	= 150 m to 1.6 km
Area	= 1–200 ha
Perimeter length	= 360 m to 5.1 km

Alternative calculation methods are available for values outside the range limits.

[1] Alexander, M.E.; Lawson, B.D.; Stocks, B.J.; Van Wagner, C.E. 1984. User guide to the Canadian Forest Fire Behavior Prediction System: rate of spread relationships. Interim edition. Environ. Can., Can. For. Serv., Fire Danger Group, Ottawa, Ontario.

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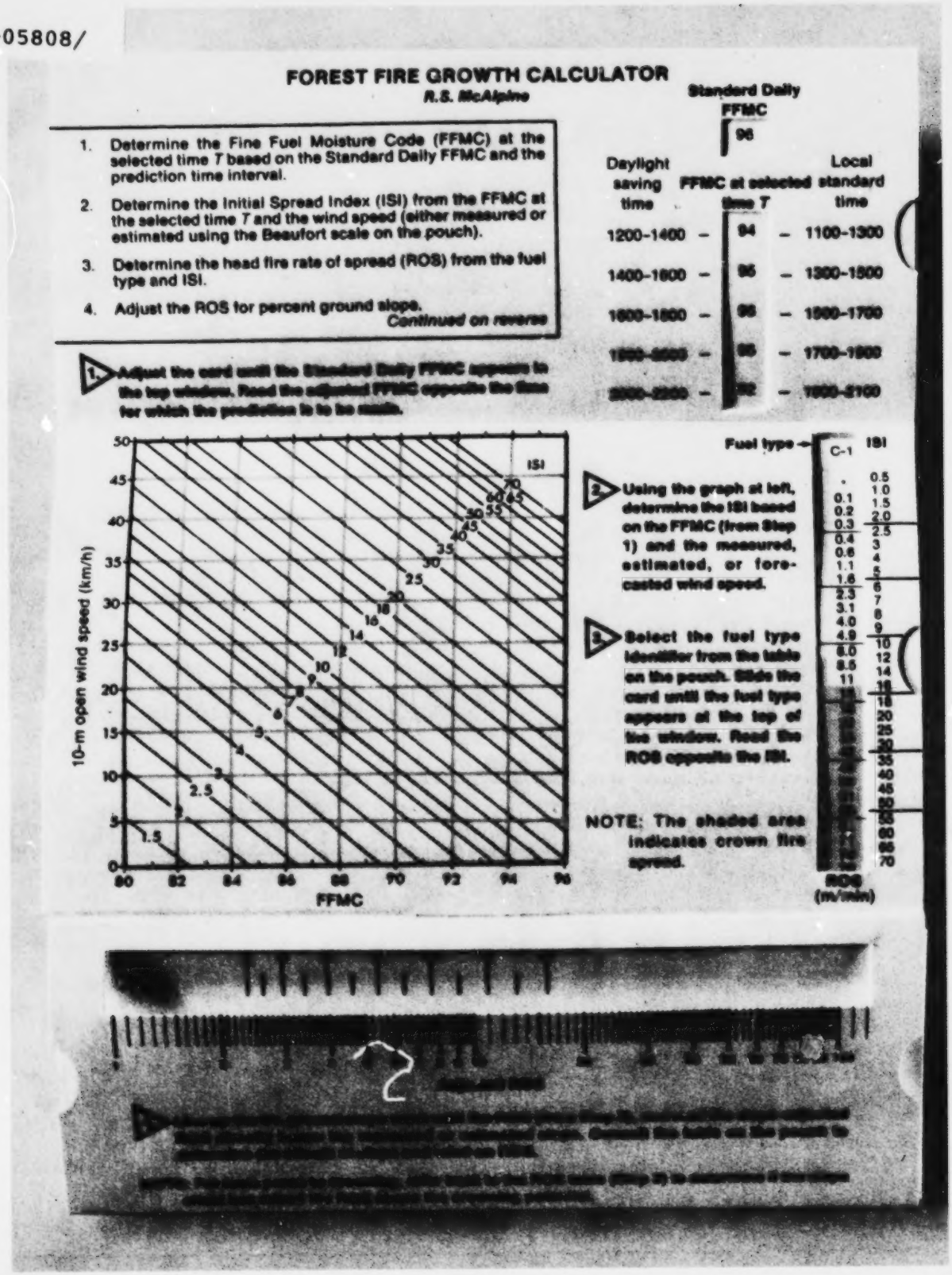
FOREST FIRE GROWTH CALCULATOR
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1. Determine the Fine Fuel Moisture Code (FFMC) at the selected time T based on the Standard Daily FFMC and the prediction time interval.
2. Determine the Initial Spread Index (ISI) from the FFMC at the selected time T and the wind speed (either measured or estimated using the Beaufort scale on the pouch).
3. Determine the head fire rate of spread (ROS) from the fuel type and ISI.
4. Adjust the ROS for percent ground slope.
Continued on reverse
Standard Daily FFMC
96
Daylight saving time
FFMC at selected time T
Local standard time
1200-1400 – 94 – 1100-1300
1400-1600 – 95 – 1300-1500
1600-1800 – 96 – 1500-1700
1800-2000 – 95 – 1700-1900
2000-2200 – 92 – 1900-2100
1. Adjust the card until the Standard Daily FFMC appears in the top window. Read the adjusted FFMC opposite the time for which the prediction is to be made.
10-m open wind speed (km/h)
FFMC
ISI
2. Using the graph at left, determine the ISI based on the FFMC (from Step 1) and the measured, estimated, or forecasted wind speed.
3. Select the fuel type identifier from the table on the pouch. Slide the card until the fuel type appears at the top of the window. Read the ROS opposite the ISI.
NOTE: The shaded area indicates crown fire spread.
Fuel type
C-1
ISI
ROS (m/min)

Figure 1. Front and back views of the fire growth calculator and accompanying pouch.

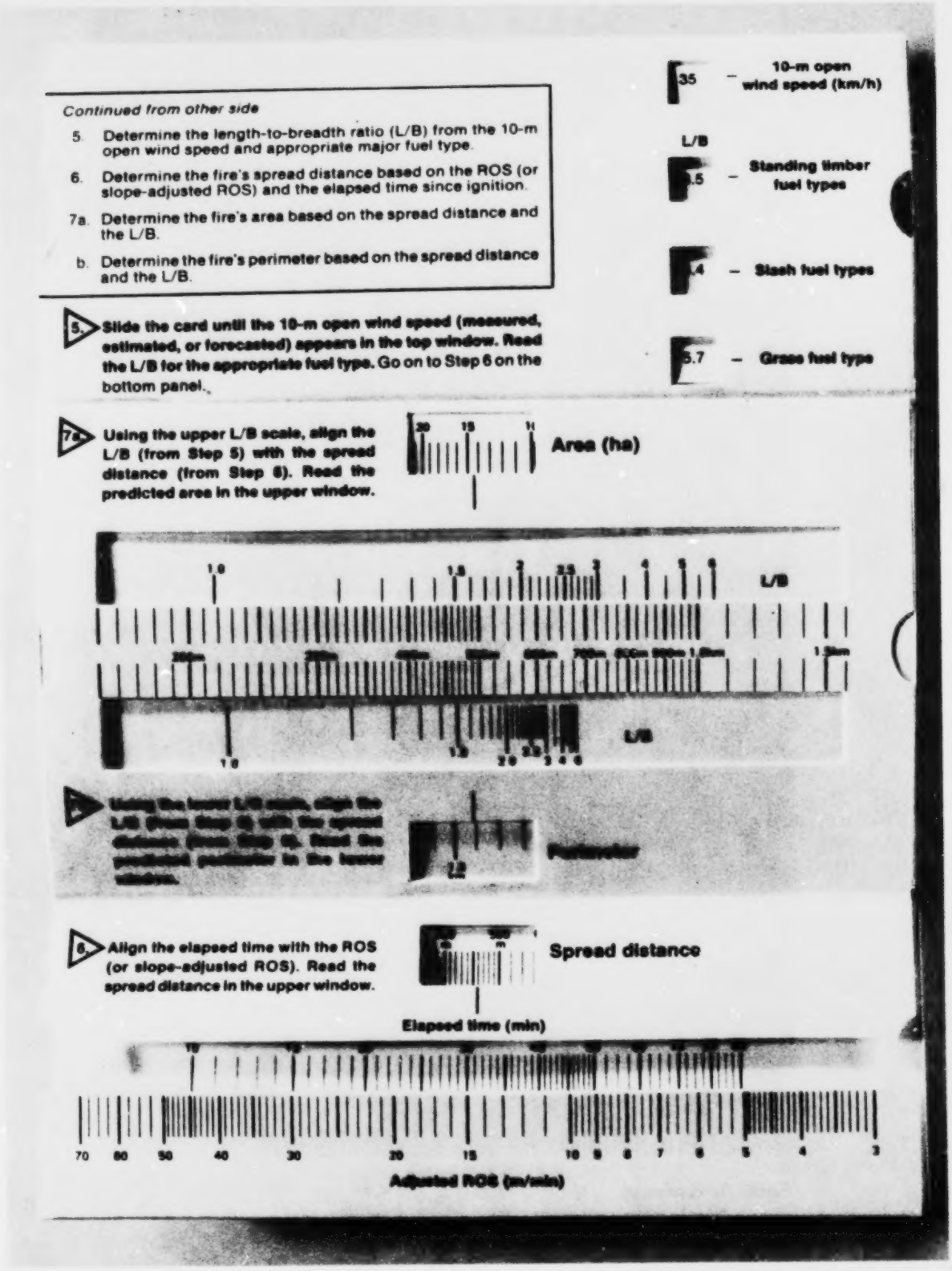
Continued from other side
5. Determine the length-to-breadth ratio (L/B) from the 10-m open wind speed and appropriate major fuel type.
6. Determine the fire's spread distance based on the ROS (or slope-adjusted ROS) and the elapsed time since ignition.
7a. Determine the fire's area based on the spread distance and the L/B.
b. Determine the fire's perimeter based on the spread distance and the L/B.
35 – 10-m open wind speed (km/h)
L/B
1.5 – Standing timber fuel types
2.4 – Slash fuel types
5.7 – Grass fuel type
5. Slide the card until the 10-m open wind speed (measured, estimated, or forecasted) appears in the top window. Read the L/B for the appropriate fuel type. Go on to Step 6 on the bottom panel.
7a. Using the upper L/B scale, align the L/B (from Step 5) with the spread distance (from Step 6). Read the predicted area in the upper window.
Area (ha)
L/B
L/B
Perimeter
6. Align the elapsed time with the ROS (or slope-adjusted ROS). Read the spread distance in the upper window.
Spread distance
Elapsed time (min)
Adjusted ROS (m/min)

Figure 1. continued.

FOREST FIRE GROWTH CALCULATOR

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Canadian Forest Fire Behavior Prediction System fuel types

Group	Identifier	Description
Coniferous	C-1	Spruce-lichen woodland
	C-2	Boreal spruce
	C-3	Mature jack or lodgepole pine
	C-4	Immature jack or lodgepole pine
	C-5	Red and white pine
	C-6	Red pine plantation[1]
	C-7	Ponderosa pine-Douglas-fir
Deciduous	D-1	Leafless aspen
Mixed wood	M-1	Boreal mixed wood, leafless[2]
	M-2	Boreal mixed wood, summer[2]
Slash	S-1	Jack or lodgepole pine slash
	S-2	Spruce-balsam slash
	S-3	Coastal cedar-hemlock-Douglas-fir slash
Open	O-1	Grass[3]

Rate of spread relationships available for three mean stand height ranges: <10 m, 10-20 m, and >20 m.

Must specify percent softwood (S) and hardwood (H) species composition. Three commonly accepted combinations have been included in the fire growth calculator: 75S:25H, 50S:50H, and 25S:75H.

[1] Standard fuel load is 3 t/ha, 100% cured.

Figure 1. continued.

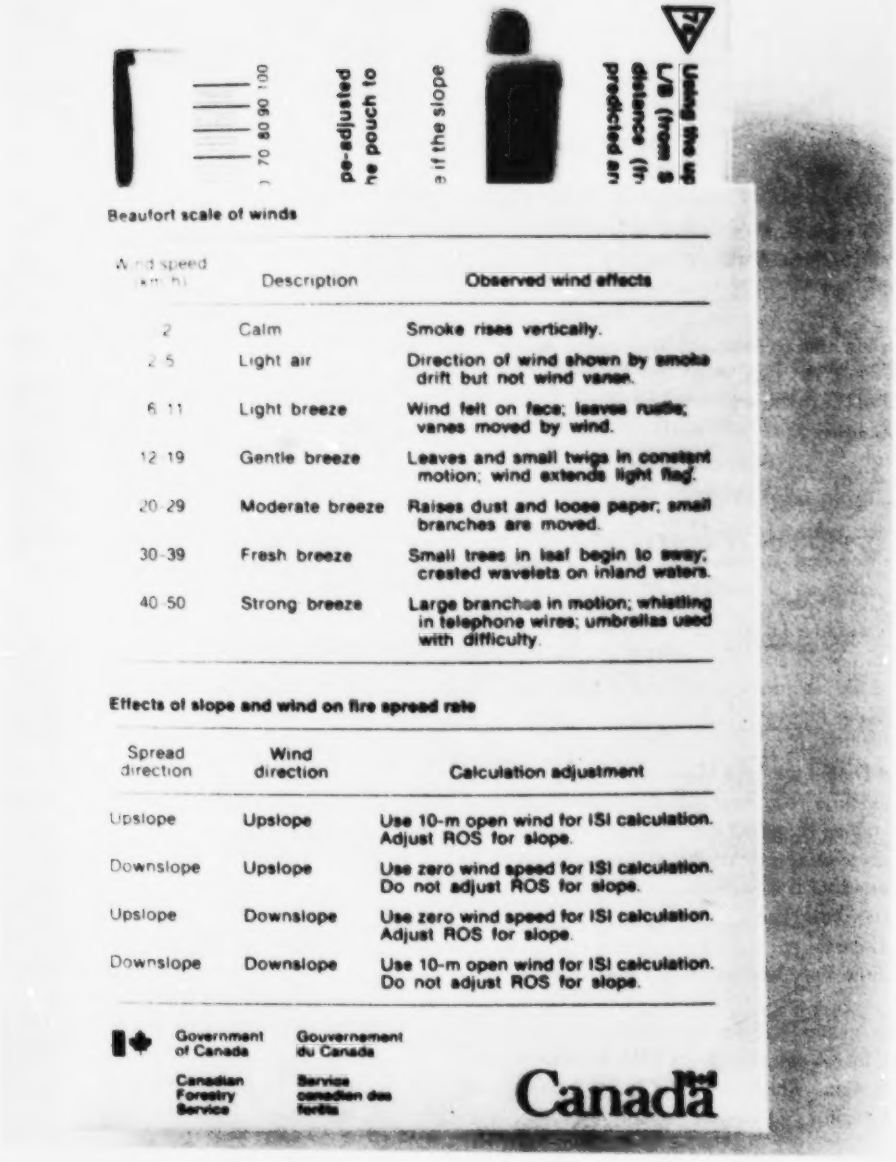
Beaufort scale of winds
Wind speed km/h
Description
Observed wind effects
2 Calm Smoke rises vertically.
2-5 Light air Direction of wind shown by smoke drift but not wind vanes.
6-11 Light breeze Wind felt on face; leaves rustle; vanes moved by wind.
12-19 Gentle breeze Leaves and small twigs in constant motion; wind extends light flag.
20-29 Moderate breeze Raises dust and loose paper; small branches are moved.
30-39 Fresh breeze Small trees in leaf begin to sway; crested wavelets on inland waters.
40-50 Strong breeze Large branches in motion; whistling in telephone wires; umbrellas used with difficulty.
Effects of slope and wind on fire spread rate
Spread direction
Wind direction
Calculation adjustment
Upslope Upslope Use 10-m open wind for ISI calculation. Adjust ROS for slope.
Downslope Upslope Use zero wind speed for ISI calculation. Do not adjust ROS for slope.
Upslope Downslope Use zero wind speed for ISI calculation. Adjust ROS for slope.
Downslope Downslope Use 10-m open wind for ISI calculation. Do not adjust ROS for slope.
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Figure 1. continued.

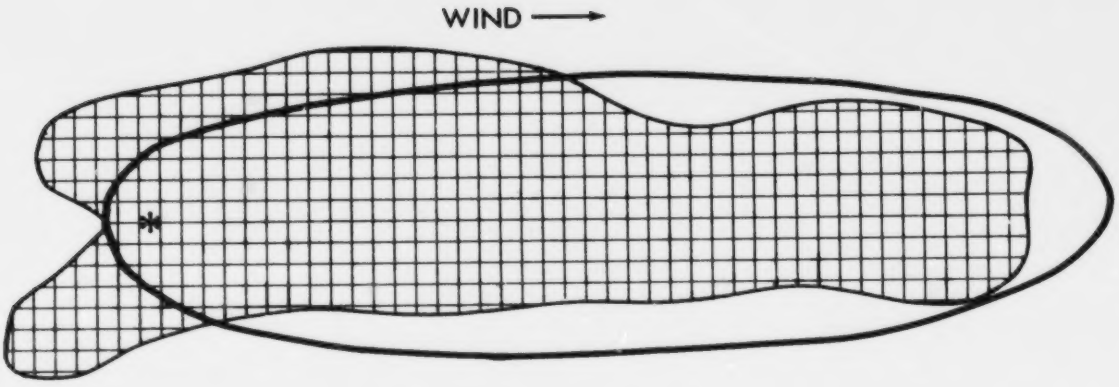

Figure 2. Comparison of actual and predicted elliptical fire growth spreading from a point source with a directionally stable wind.

Due to the interim nature of the present version of the FBP System, the FGC must also be considered an interim model. When the first complete edition of the FBP System is published, a revised version of the FGC will be produced.

OPERATING PROCEDURES

The FGC consists of a carrying pouch and three sliding cards within a 15.5 × 22.5 cm envelope, which folds down to pocket size (Fig. 1). The operator should first have all the information required to produce a fire growth estimate:

- Standard Daily Fine Fuel Moisture Code (FFMC)
- Prediction time (h); local standard time (LST) or daylight saving time (DST)
- 10-m open wind speed (km/h); measured, estimated, or forecasted for the prediction time
- FBP System fuel type
- Ground slope (%)
- Elapsed time since ignition (min)

Most of the values can be approximated on site, if necessary. The exception is the FFMC, a component of the FWI System, which must be known before the calculations begin.

The following are the steps to be taken to predict forest fire growth using the FGC.

1. Select the time (between 1200 and 2200 DST or 1100 and 2100 LST) for which the prediction is to be made. Slide the top card until the **Standard Daily FFMC** for the day appears in the top window. Read the adjusted FFMC opposite the time for which the prediction is to be made.

2. Determine either the measured **10-m open wind speed** or make an estimate of wind speed using the Beaufort scale (Turner and Lawson 1978), which is printed on the pouch. Using this wind speed and the **adjusted FFMC** from Step 1, determine the Initial Spread Index (ISI) from the graph on the center panel.

3. Select an **FBP System fuel type** (from the listing on the pouch) that best describes the fuel complex in which the fire is burning. Slide the center card until the FPB System fuel type appears at the top of the window. The predicted head fire rate of spread (ROS) can then be read opposite the ISI determined in Step 2. Note that the shaded area on the ROS table indicates crown fire spread.

4. The effect of ground slope on a fire's forward spread is variable, depending on the direction of the wind in relation to the slope. A significant slope must be accounted for in the fire prediction. Initially, judge the slope direction with respect to the wind direction, and then consult Table 1 for specific instructions (Table 1 is also printed on the pouch for field reference).

   The **percent ground slope** is estimated by dividing the vertical rise or fall in elevation by the horizontal ground distance and then multiplying by 100. Adjust the card until the 0% ground slope mark is aligned with the predicted ROS from Step 3. Read the slope-adjusted ROS directly below the estimated ground slope. For fuels prone to crowning, refer back

Table 1. Interactive effects of slope and wind on fire rate of spread (ROS)

Spread direction	Wind direction	Calculation adjustment
Upslope	Upslope	Use 10-m open wind for ISI calculation. Adjust ROS for actual percent slope.
Downslope	Upslope	Use zero wind speed for ISI calculation. Do not adjust ROS for percent slope.
Upslope	Downslope	Use zero wind speed for ISI calculation. Adjust ROS for actual percent slope.
Downslope	Downslope	Use 10-m open wind for ISI calculation. Do not adjust ROS for percent slope.

to the ROS table (Step 3) to determine if the slope effect has raised the ROS above the crowning potential.

5. Using the second side of the FGC, determine the length-to-breadth ratio (L/B) by adjusting the top card until the **10-m open wind speed** used in Step 2 appears in the top window. Read the L/B for the appropriate broad fuel type (standing timber, slash, or grass). Leave the card in place for easy reference back to the L/B value.

6. The fire spread distance is determined with the **ROS** from Step 3 or the **adjusted ROS** from Step 4 and the **elapsed time since ignition**. The elapsed time since ignition is the total time in minutes from the time the fire began burning at its present rate (from a point ignition) until the time in the future for which you wish to make the prediction. (For example, if a fire was reported or estimated to have started 15 min ago and the prediction is for 30 min from now when arrival is expected, the elapsed time is 15 + 30 = 45 min.) Adjust the bottom card until the ROS and the elapsed time since ignition line up, and read the spread distance from the upper window (spread distance = ROS × elapsed time).

7. Finally, calculate the area and perimeter length.

   7a. Using the upper **L/B** scale, slide the center card until the L/B value from Step 5 lines up with the **spread distance** determined in Step 6. Read the predicted area in hectares (ha) from the top window.

   7b. The same procedure is followed with the lower L/B scale to obtain a perimeter projection. Perimeter length is displayed in either metres (m) or kilometres (km).

Six examples of forest fire growth calculations are presented in Table 2. These examples can be worked through by users familiarizing themselves with the operating procedures for the FGC. Note that examples 1 and 6 are the same except for a change in the Standard Daily FFMC. This small change resulted in a 144% increase in perimeter length and a 266% increase in area.

Table 2. Six examples of forest fire growth calculations using the FGC

Input/output	Example no. 1	2	3	4	5	6
Standard Daily FFMC	89	90	94	91	90	92
Time of day, LST	1233	1603	1514	1157	1658	1233
Adjusted FFMC	87	90	94	89	90	90
10-m open wind (km/h)	18	10	21	12	27	18
Initial Spread Index	7	7	22	6	16	10
FBP System fuel type	C-4	C-2	C-1	S-1	S-2	C-4
ROS on level (m/min)	7.6	5.7	27	8.9	12	14
Ground slope (%)	0	10	0	5	0	0
Slope-adjusted ROS (m/min)	7.6	7.0	27*	9.8	12	14*
Elapsed time (min)	45	60	75	30	20	45
Spread distance	330 m	428 m	2.05 km	300 m	240 m	630 m
Area (ha)	5.6	19.5	>150	2.3	0.7	20.5
Perimeter length	900 m	1.59 km	>5 km	820 m	545 m	1.71 km

* Denotes crown fire.

CONCLUDING REMARKS

The FGC is designed to give quick estimates of fire growth. In operational fire situations, if time and resources permit, a more-thorough calculation is possible using either the FBP System Worksheet and User Guide or FBP System computer software. Potential users of the FGC include bird-dog officers, initial-attack crew leaders, or anyone familiar with the FBP System who needs fast estimates of fire growth. The FGC can also be used to estimate line fire growth, without area or perimeter calculation, based on the spread distance calculation.

The ability to work backward (i.e., given final results, work toward the initial inputs) allows other uses of the FGC, such as estimating time of ignition, FFMC at the fire location, or other input parameters. The effect on final outputs of slight variations in one or more of the inputs also becomes easy to see.

The FGC is subject to the same constraints as the FBP System, including assumed uniformity of environmental conditions over the area considered in a single prediction and the inability to compensate for the slope effect on the L/B ratio, which causes overprediction of fire area and flank spread.

Single copies of the FGC are available from the Northern Forestry Centre.

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June 1986

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